STEVENS SHUTTLE SYSTEM

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SYS 611 : MODELING AND SIMULATION

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INTRODUCTION

STUDY OBJECTIVES

The study is based on the Stevens Shuttle System. The shuttle service offers free access for Stevens's students and staff throughout the city of Hoboken, NJ all throughout the year. There are four lines (routes) for this shuttle service: Blue, Red, Green and Gray. The term project created is to build a simulation model for the Red line which covers the southern portion of Hoboken with the following stops

- *HOWE CENTER (START AND DROP OFF STOP)*
- *MADISON AND 6TH STREET (STOP 1)*
- *JACKSON 6TH AND 7TH (STOP 2)*
- *MADISON AND 8TH STREET (STOP 3)*
- *MADISON AND 9TH STREET (STOP 4)*

And thereby suggest the shuttle service to increase/decrease the frequency of shuttles during a period of time.

SYSTEM BOUNDARY

In a broader sense, the system boundary is limited to Hoboken. In detail, the system boundary for the project is the loop formed by the four stops of Howe Center - to Madison and 6th – to Jackson 6th and 7th – to Madison and 8th - to Madison and 9th and back to Howe Center. The data chosen is for the whole month of November. Only the weekdays are considered for the model. STOP 1 and STOP 2 were not considered for the model because of low passenger activity.

SYSTEM VARIABLES

The state variables for the system are:

- *Number of passengers in the bus.*
- *Time between the two stops*
- *Current location (stop) of the bus.*
- *Arrival time of a passenger at the stop*

The derived state variables:

- *The number of passengers in the bus after each stop*
- *Waiting time of the passenger*
- *Next stop of the bus*

The transition states will include:

- *The transition of the bus from one location to other.*

The system is a DYNAMIC STOCHASTIC MODEL, as its attributes move/change with respect to time and it has at least one input with random values within reference frame.

The random variables include:

- *Arrival of passenger at the bus stop*
- *Stop at which the passenger will get off.*

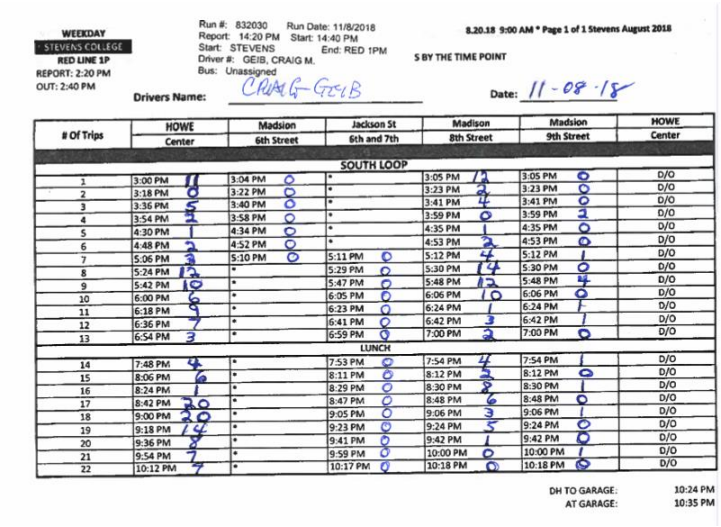
KEY PERFORMANCE MEASURES

The key performance indicator in our model is to calculate the average waiting time of the passengers for different durations of time in the day throughout the period of the month of November and thereby suggest the frequency of shuttles to be incorporated for these durations.

MODELING APPROACH

DATA COLLECTION

The raw data was collected from the Office of Residence at Howe center and Academy bus service, Hoboken. It had the timetable of shuttles along with the people getting on the shuttle at each stop, for the month of November. To work with this data was challenging as it had no dataset in digital format. So we had to create a dataset based on these numbers. The figure 1 is the raw data we acquired from the Office of Residence at Howe center and Academy bus service.



WEEKDAY
STEVENS COLLEGE
RED LINE 1P
REPORT: 2:20 PM
OUT: 2:40 PM

Run #: 832030 Run Date: 11/8/2018
Report: 14:20 PM Start: 14:40 PM
Start: STEVENS End: RED 1PM
Driver #: GEIB, CRAIG M.
Bus: Unassigned

8.20.18 9:00 AM * Page 1 of 1 Stevens August 2018

S BY THE TIME POINT

Drivers Name: CRAIG GEIB Date: 11-08-18

# Of Trips	HOWE Center	Madison 6th Street	Jackson St 6th and 7th	Madison 8th Street	Madison 9th Street	HOWE Center
			SOUTH LOOP			
1	3:00 PM 11	3:04 PM 0	*	3:05 PM 12	3:05 PM 0	D/O
2	3:18 PM 0	3:22 PM 0	*	3:23 PM 2	3:23 PM 0	D/O
3	3:36 PM 5	3:40 PM 0	*	3:41 PM 4	3:41 PM 0	D/O
4	3:54 PM 2	3:58 PM 0	*	3:59 PM 0	3:59 PM 3	D/O
5	4:30 PM 1	4:34 PM 0	*	4:35 PM 1	4:35 PM 0	D/O
6	4:48 PM 2	4:52 PM 0	*	4:53 PM 2	4:53 PM 0	D/O
7	5:06 PM 3	5:10 PM 0	5:11 PM 0	5:12 PM 4	5:12 PM 1	D/O
8	5:24 PM 12	*	5:29 PM 0	5:30 PM 14	5:30 PM 0	D/O
9	5:42 PM 10	*	5:47 PM 0	5:48 PM 12	5:48 PM 4	D/O
10	6:00 PM 6	*	6:05 PM 0	6:06 PM 10	6:06 PM 0	D/O
11	6:18 PM 4	*	6:23 PM 0	6:24 PM 1	6:24 PM 1	D/O
12	6:36 PM 7	*	6:41 PM 0	6:42 PM 3	6:42 PM 1	D/O
13	6:54 PM 3	*	6:59 PM 0	7:00 PM 3	7:00 PM 0	D/O
			LUNCH			
14	7:48 PM 4	*	7:53 PM 0	7:54 PM 4	7:54 PM 1	D/O
15	8:06 PM 6	*	8:11 PM 0	8:12 PM 3	8:12 PM 0	D/O
16	8:24 PM 1	*	8:29 PM 0	8:30 PM 2	8:30 PM 1	D/O
17	8:42 PM 20	*	8:47 PM 0	8:48 PM 6	8:48 PM 0	D/O
18	9:00 PM 20	*	9:05 PM 0	9:06 PM 3	9:06 PM 1	D/O
19	9:18 PM 14	*	9:23 PM 0	9:24 PM 5	9:24 PM 0	D/O
20	9:36 PM 8	*	9:41 PM 0	9:42 PM 1	9:42 PM 0	D/O
21	9:54 PM 7	*	9:59 PM 0	10:00 PM 0	10:00 PM 1	D/O
22	10:12 PM 7	*	10:17 PM 0	10:18 PM 0	10:18 PM 0	D/O

DH TO GARAGE: 10:24 PM
AT GARAGE: 10:35 PM

Figure 1

The dataset was transformed into the excel sheet as shown in figure 2

DATE	NO OF TRIPS	TIME		n: HOWE CENTE	6TH	8TH	9TH
11/8/2018	1	5:00:00 PM		11	0	3	
11/8/2018	2	5:18:00 PM		6	0	2	0
11/8/2018	3	5:36:00 PM		4	0	3	0
11/8/2018	4	5:54:00 PM		1	0	4	0
11/8/2018	5	6:12:00 PM		2	0	0	0
11/8/2018	6	6:30:00 PM		1	0	0	0
11/8/2018	7	6:48:00 PM		6	0	0	1
11/8/2018	8	7:06:00 PM		6	0	0	0
11/8/2018	9	7:24:00 PM		11	0	0	0
11/8/2018	10	7:42:00 PM		8	0	0	0
11/8/2018	11	8:00:00 PM		5	0	0	0
11/8/2018	12	8:18:00 PM		4	0	0	0
11/8/2018	13	8:36:00 PM		12	0	0	0
11/8/2018	14	8:54:00 PM		11	0	0	0
11/9/2018	15	7:30:00 AM		0	0	0	0
11/9/2018	16	7:48:00 AM		0	0	0	0
11/9/2018	17	8:06:00 AM		0	0	0	1
11/9/2018	18	8:24:00 AM		0	0	3	1
11/9/2018	19	8:42:00 AM		1	2	5	2
11/9/2018	20	9:00:00 AM		0	0	2	0
11/9/2018	21	9:18:00 AM		0	0	5	0
11/9/2018	22	9:36:00 AM		0	1	11	2
11/9/2018	23	9:54:00 AM		0	1	6	0
11/9/2018	24	12:00 AM		1	0	4	1

Figure 2

The total number of trips per day is 35 trips. Therefore we have 1080 samples of trips.

A model was developed with the following parameters:

- *Trip number*
- *Trip time*
- *Number of passengers in the bus (N)*
- *Number of passengers at Howe center- N1*
- *Number of passengers at (8^{th}) – N2*
- *Number of passengers at (9^{th}) – N3*
- *Cumulative waiting time at each of the 3 stops*
- *Average waiting time at each stops*

DEVELOPING THE MODEL

The system under study is a Dynamic- Stochastic system, Monte-Carlo simulation was adopted.

The step approach followed in developing the model is:

1) IDENTIFY THE NUMBER OF SAMPLES

   The number of samples identified were 1080.

2) IDENTIFY THE PRIMARY RANDOM VARIABLE

   The state variables we were interested in were Number of passengers in the bus, the shuttle stop and the time of arrival of each passenger at each bus stop at a point of time.

3) TO IDENTIFY THE DERIVED STATE VARIABLE

   The derived state variables important for the model were identified as Cumulative waiting time and average waiting time at each bus stop at a given point of time.

4) INCORPORATING PROCESS GENERATORS AND RECORDS

Finding out arrival time and wait time of each and every passenger at each and every stop throughout the day is not feasible. So, after surveying a few colleagues' experience of shuttle use and the pattern of passengers at the bus stop from data collected.

We incorporated different random process generators for different periods of time for different shuttle stops. =RANDBETWEEN (lower limit of wait time, upper limit of wait time). 12 Process generators were incorporated for Morning 7:30am – 9:30am, Morning 9:30am to 11:30 am, Afternoon slot, evening slot and night slot for 3 different stops.

VALIDATION

The main purpose of the validation is to know whether the model created actually resembles the system or to have the confidence to in its capacity for its actual operations. The outputs were used as measures of effectiveness with the actual data. It was found that the structure of the model closely resembles the actual system and the simulated results closely relate to the actual field situation. This model can be incorporated on other lines: Green, Blue, Gray lines. It can also be extended for other bus services.

=SUM(D2,G2,J2)

	A	B	C	D	E	F	G	H	I	J	K	L	M
	Trip	TIME	No of people in the bus	N(howe)	Cumulative WaitingTi	Average Wait tin	N(8th)	Cumulative waiting time	Average Wait	N (9th)	Cumulative waiting time	Average Wait time (9th)	
	0	7:30:00 AM	2	0	0	0	2	28	14	0	0	0	
	1	7:48:00 AM	6	1	6	6	3	21	7	2	8	4	
	2	8:06:00 AM	4	0	0	0	3	12	4	1	7	7	
	3	8:24:00 AM	3	1	6	6	2	8	4	0	0	0	
	4	8:42:00 AM	5	0	0	0	3	18	6	2	4	2	
	5	9:00:00 AM	3	0	0	0	3	23	7.666666667	0	0	0	
	6	9:18:00 AM	8	1	15	15	7	90	12.85714286	0	0	0	
	7	9:36:00 AM	9	0	0	0	8	113	14.125	1	4	4	
	8	9:54:00 AM	16	2	9	4.5	14	45	3.214285714	0	0	0	
	9	10:12:00 AM	15	2	8	4	12	57	4.75	1	4	4	
	10	10:30:00 AM	14	3	15	5	11	101	9.181818182	0	0	0	
	11	10:48:00 AM	16	1	8	8	14	74	5.285714286	1	4	4	
	12	11:06:00 AM	9	1	11	11	8	110	13.75	0	0	0	
	13	11:24:00 AM	16	1	15	15	14	65	4.642857143	1	3	3	
	14	3:00:00 PM	16	9	92	10.22222222	6	32	5.333333333	1	10	10	
	15	3:18:00 PM	20	16	13	0.8125	4	45	11.25	0	0	0	
	16	3:36:00 PM	15	9	5	0.555555556	4	30	7.5	2	10	5	
	17	3:54:00 PM	12	8	68	8.5	4	8	2	0	0	0	
	18	4:30:00 PM	12	7	26	3.714285714	2	28	14	3	11	3.666666667	
	19	4:48:00 PM	19	15	69	4.6	1	43	43	3	8	2.666666667	
	20	5:06:00 PM	22	16	74	4.625	3	28	9.333333333	3	13	4.333333333	

Figure 3

RESULTS AND ANALYSIS

The results for the simulation model were quite realistic and matched the actual data which have been analyzed visually too.

AVERAGE WAITING TIMES FOR DIFFERENT STOPS:

- *Average waiting time for HOWE center: 5.36 minutes*
- *Average waiting time for Madison and 8th : 6.05 minutes*
- *Average waiting time for Madison and 9th : 2.4 minutes*

AVERAGE NUMBER OF PASSENGERS IN THE BUS:

- *Average number of passengers in the bus for all times: 11.7 ~ 12 passengers.*

VISUAL ANALYSIS

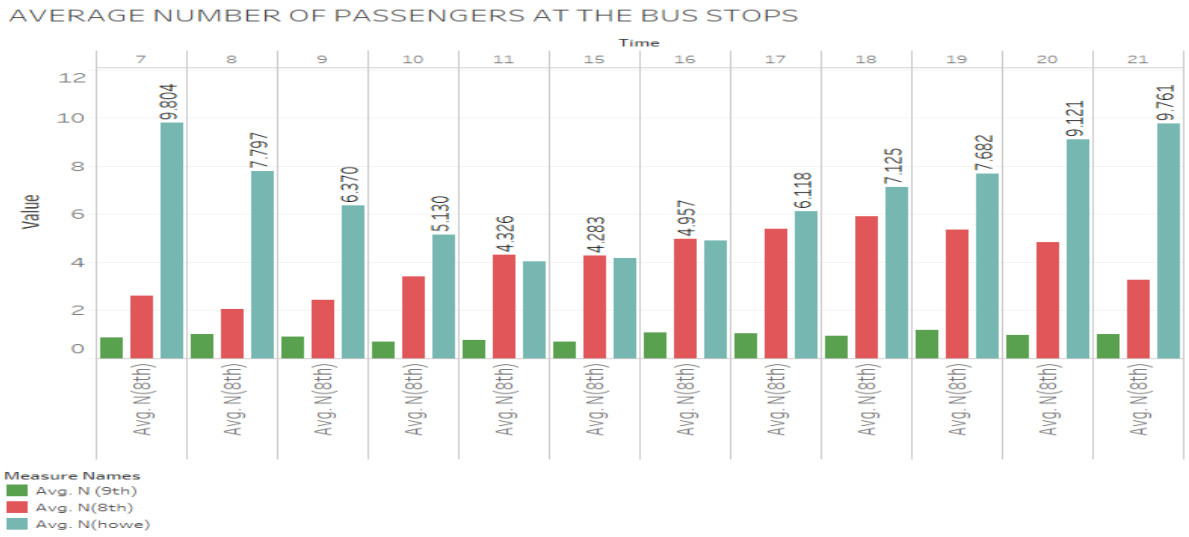


Figure 4

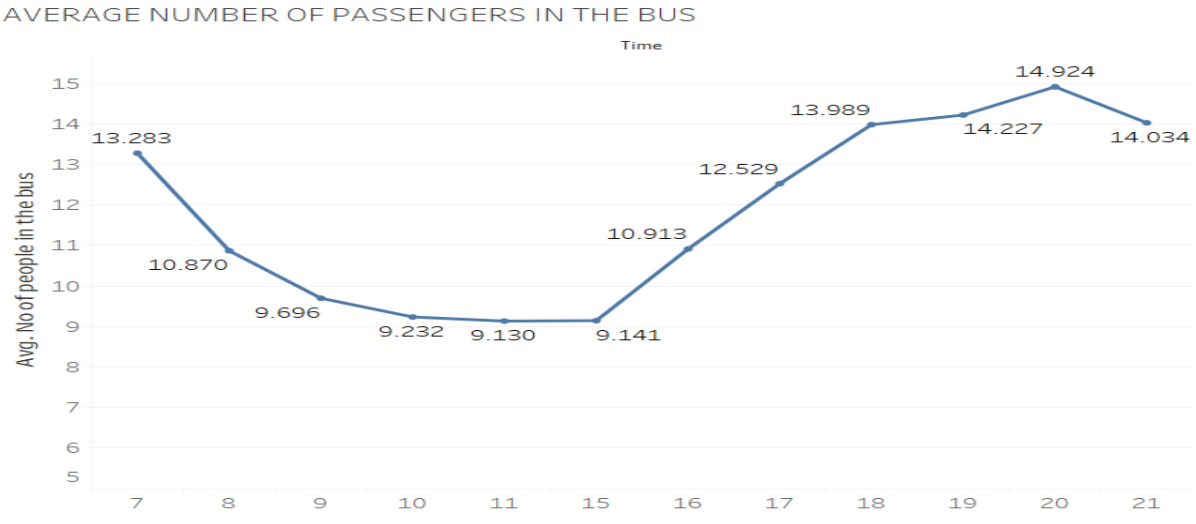


Figure 5

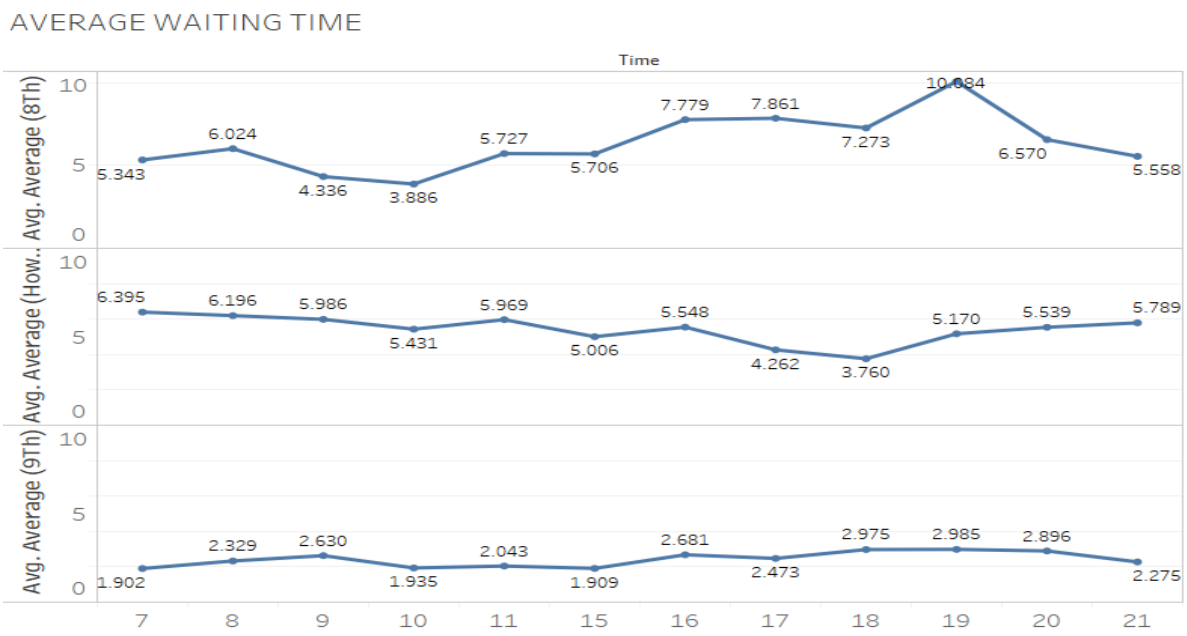


Figure 6

CONCLUSION

It can be seen that there is a shortage of seats for passengers and a lot of waiting period in the peak times of morning 8-9am, afternoon 12-2pm and late evening around 8-9pm. Stevens shuttle should introduce multiple shuttles for this line at the pointed time intervals to make it convenient for the users.

DISCUSSION AND FURTHER SCOPE

Given more time and detailed data we can analyze more prospects like to focus on the operating cost of the shuttle and thereby conclude whether increasing frequency is a good decision or not. Also instead of just one line we can focus on the remaining three lines for all the stops. The data under study can be increased. Currently, the data is for one month, next extension to this can be to analyze the use of shuttle service with respect to different seasons. It was a great and challenging task to analyze this because of a lot of limitations and an extension to this would be of great help.

REFERENCES

Stevens bus shuttle service (Data)

611 Course material